

Hot Iron

Winter 2013
Issue 82

Contents

Fourier & Harmonics
Harmonic theory!
Simple sig generator
MOSFETs & the Devil
Rig Ideas
Valve output networks
Snippets!
HF in Riyadh
Encasing rigs
Happy Christmas!!

The Walford Electronics web-site is also at
www.walfordelectronics.co.uk

Editorial

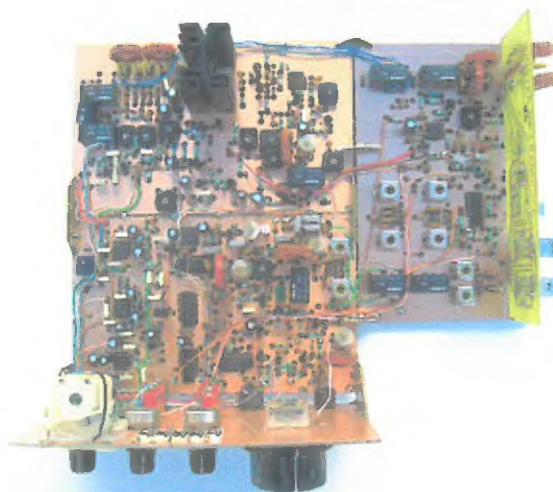
In various ramblings about future rig possibilities with Peter Thornton, I was led to various sites and designs for clever simple rigs that managed to squeeze high performance out of a very limited number of active devices - transistors of one type or another. Ingenious ideas have led to viable receivers (mostly) with the absolute minimum of devices. Often, especially where these are 'high impedance' active devices like valves, there is a large dependence on transformers - both for RF and audio with consequently lots of iron and copper! The latter are now like hens teeth in comparison to the transistors or even valves - more or less unobtainable and certainly not viable in a modern kit! The transistors cost a few pence literally (though definitely not true of valves!) so there is absolutely no need to complicate circuits trying to minimise the number of transistors! In fact, in my recent designs, the cost of the capacitors has been higher than that of the resistors and both are quite hard to weed out of a design!

But then try and do without some of these wound components - its very challenging; especially where there is a need to push a few hundred milli-amps into a low resistance load (eg a loud speaker or modulator). Even in a transistorised rig, the once ubiquitous TOKO adjustable RF coils and trimmers are becoming relatively expensive. So the design emphasis has to change from cutting down on active devices to getting rid of the wound parts! For a valve project you now need to do both!! Tim

Kit Developments

Some good review publicity recently in PW has kept me busy making up FiveFET kits but meanwhile the Minster has also made good progress. The Basic TCVR is now working well and I have added the RF Extras option (right) that turns it into an any two fitted bands 20 - 80m plus a plug-in card for any or all bands 10 - 160m! Its quite a project & writing it all up is taking ages! Watch the website for progress.

I am also now working up some ideas for a two new projects - firstly a specialist CW RX/TX pair, and secondly a new entry level superhet RX with an intended phone TX option! See later and let me know your thoughts please! G3PCJ



Hot Iron is a quarterly subscription newsletter for members of the Construction Club. Membership costs £8 per year with the first issue for each year appearing in September. Those people joining later in the year will be sent the earlier issues for that year. Membership is open to all and articles or questions or comments or notes about any aspect of electronics—principally on amateur radio related topics— is very welcome. Notes on member's experience building their own gear, from kits or otherwise is most interesting to other constructors. To keep it interesting, your thoughts and ideas are required please! For membership, I only need your name and address and subscription. Send it or any other suggestions to Tim Walford, Walford Electronics, Upton Bridge Farm, Long Sutton, Langport, Somerset TA10 9NJ or walfor@globalnet.co.uk © G3PCJ

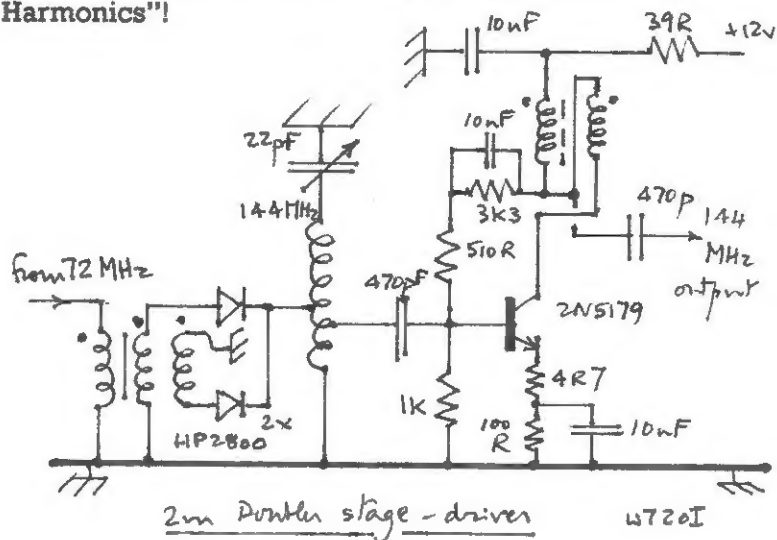
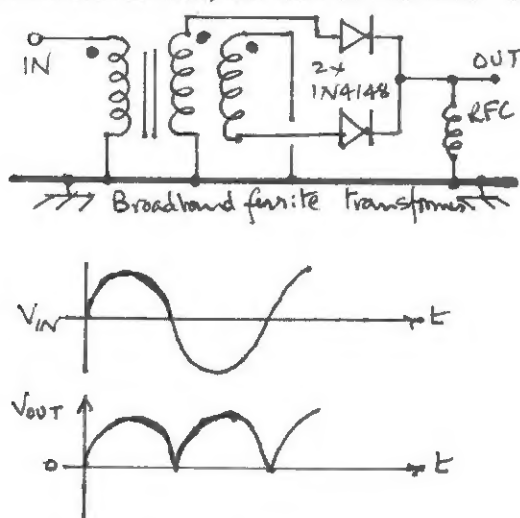
Mr. Fourier and DC Harmonics by Peter Thornton

I bet you always thought "harmonics" were bits of a sine wave, didn't you? (I hope not! Ed.) All to do with distortion, frequency multiplication, low pass filters on transmitter outputs, etc?

Well, here's the outcome of a recent discussion regarding harmonics, mixers and transmitters. I was asked "does a 'triangle' wave contain odd or even harmonics and how does the amplitude of the harmonics decrease, as the harmonics go higher and higher?" Mr. Fourier, an 18th Century mathematician, discovered how the various harmonics add to create ANY waveshape. That's at least 100 years before anybody knew about electricity, sine waves, or radio! Mr. Fourier was one exceedingly bright cookie; as well as maths, he first described the Earth's "greenhouse" effect!

Much WIKI searching, memory dredging and text book blethering produced this rather amazing answer; thanks to Mr. Fourier, a triangle wave, square wave, (or any other *symmetrical about zero* waveform) is composed of only ODD harmonics added together; it's different amplitudes of the ascending harmonics that create the different waveshapes.

That means, then.... if you select EVEN HARMONICS of a sine wave, the result is NOT symmetrical about zero – which means there is some DC component! How do we normally make DC from a sine wave? Diodes? Full wave rectification is pure frequency doubling and Wes Hayward, W7ZOI, and Doug DeMaw W1FB use this in "Solid State for the Radio Amateur" (pages 198-199) to generate an ultra-pure local oscillator for 144MHz from an 18MHz crystal, by successive diode doublers: hence, the title of this note: "DC Harmonics"!

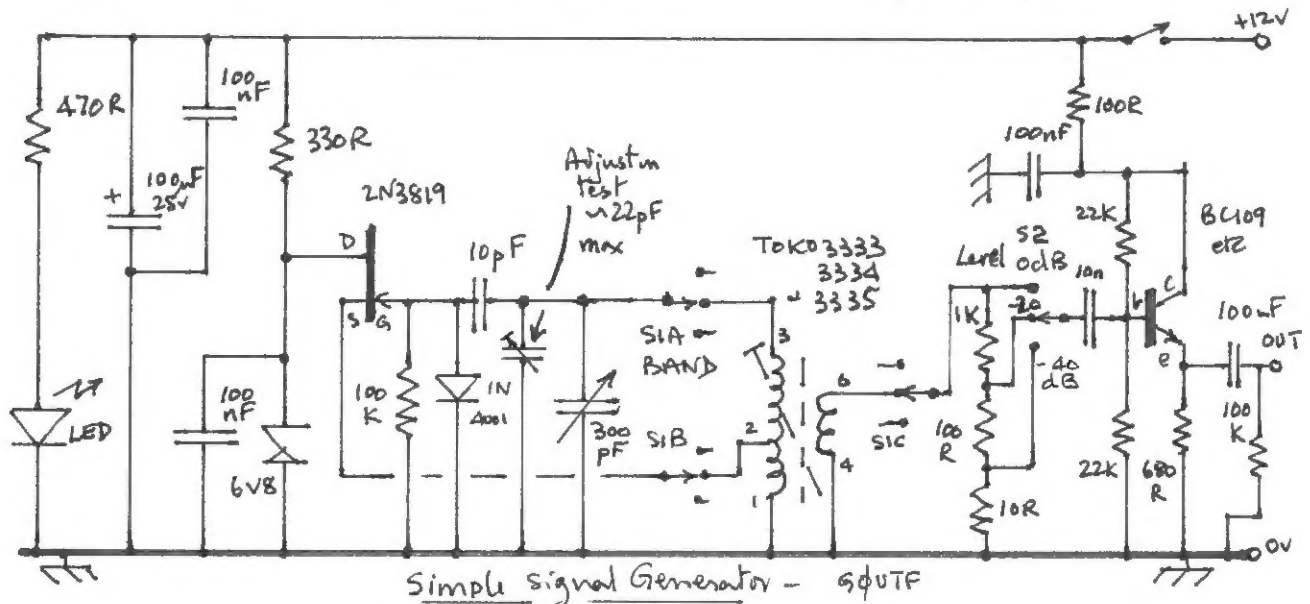


More Harmonic theory!

When the RF Extras are added to the Minster, the desired LO of 8 MHz is produced by adding the 4 MHz VFO to a 4 MHz xtal source. Hence the second harmonic of both sources is directly in the output band! This is far from ideal but the basic scheme of using a 4 MHz VFO, with various crystals, suits all the other bands so well that these 20m snags are worth tolerating! In earlier rigs with this scheme (Taunton and Bristol), it made setting up the 20m LO quite a challenge! For other reasons, in the Minster, the 4 MHz VFO signal is a square wave; Mr Fourier tells you it has odd harmonics that decrease as the inverse of the harmonic number, eg the third harmonic is one third the amplitude of the fundamental etc. But he also tell us that for a triangle wave, there are still only odd harmonics but they go down inversely as the **square** of the harmonic number, so the third is now one ninth of the fundamental and the fifth is one twenty-fifth instead of one fifth etc.. Clearly if the waveforms are not perfectly shaped there will also be some even harmonics but they will be much less pronounced in the triangle 'wave' than if a square one is input to the LO mixer! I was able to easily alter the Minster 4 MHz VFO output to a triangle wave by changing one resistor in the attenuator prior to the LO mixer, to a capacitor. This immediately reduced the unwelcome second harmonic of the VFO in the LO mixer output so making the 20m LO Bandpass filters much easier to adjust! (The fixed frequency second harmonic of the crystal is not so troublesome!) Nasty theory does have its uses!! G3PCJ

A Simple Signal Generator by David Proctor G0UTF

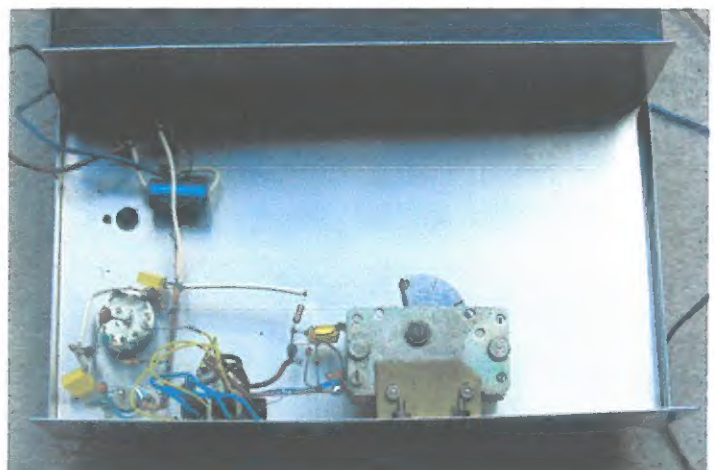
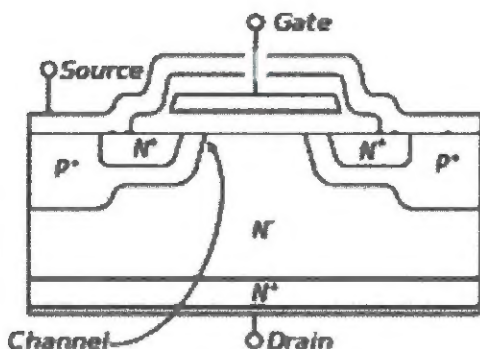
After years of "going to make one", here is my version of a sig. gen. It cost me nothing – made from bits in my junk box – even the metal case was once a QRP CW TX (hence the redundant hole!). The metal box keeps the RF at bay, only coming out of the coax socket. It is quite simple, although it took some time to get the correct circuit to obviate spurious oscillations. In 3 bands it gives 0.9 - 2.6MHz, 2.6 - 7.0MHz, 6.0MHz - 15MHz. These ranges can be changed by tweaking the TOKO coils. It has a 5:1 reduction ratio on the tuning knob and a large scale. It was built very quickly in the "ugly" style, as the photograph below right show. Output level is constant, but at the band ends is +/- 2dB. The Output level = +14dB (can be changed by the zener voltage). There are also -6dB & -26dB outputs by inbuilt attenuator. The waveform is "sinusoidal", but enough harmonics can also be heard in an RX. Does it deserve a place on your work bench?



MOSFETs and the Devil by Peter Thornton

We often think MOSFETs are a panacea for all RF power amplifier ills. Whilst they are very fast and cheap, they do have some little Devils built in.

Here is a cross section of a typical MOSFET transistor. A real device will be thousands of these individual transistors in parallel, interconnected by aluminium tracks created by photolithography on the silicon wafer surface. The electrodes are connected to the outside World by bond wires from the aluminium tracks to the device pins; the drain connection is usually the metal tab the silicon die is bonded to, the metal tab in a TO-220 package, for instance. The device shown is indicative of the structure; many different structures are used in real devices, but this diagram serves to illustrate. (Diagram below left courtesy Wikipedia)



MOSFETs and the Devil Contd

Without going into semiconductor physics, the device works like this. Voltage applied to the gate with respect to the source "inverts" the polarity of the source, from P-type to N-type, by virtue of the electric field imposed via the gate to source insulation – the region surrounding the gate in the diagram. This insulator is made of silicon dioxide and is less than 100 nanometres thick. There are 40 *millionths* of a metre to every thousandth of an inch, so 100 *nanometres* is 1/400th. of one thousandth of an inch. For comparison, a human hair is ~ 5 thousandths of an inch diameter!

The electric field created gate to source being so high (because the insulator is so thin), the P-type semiconductor inverts to become N-type, thus creating a continuous N 'channel' between the source and drain, conducting electrons from the source to the drain. Thus we have a transistor: by biasing the gate, we can change the conductivity of the 'channel'. The conductivity of the channel, the N drain region and the bond wires form the 'R_{ds on}' resistance.

Let's find some Devils! Without any gate bias or signal applied, the channel is P-type; now let's follow the semiconductor type from the drain tab upwards. N+ and N for the drain region; P for the channel; N for the source. That's an NPN transistor! And we have several P-N junctions, too, visible in the diagram; the biggest diode is the N+ and N drain to the P-type source, drawn as a diode source to drain on the device's symbol.

NPN transistors have gain and capacitances: but in a MOSFET, you can't get at the transistor to bias it, use it or neutralise it. But it's an NPN transistor all the same, and if signals can get into it, with volts applied, it will amplify them! All diodes are capable of charge storage and are voltage dependent too; thus the MOSFET is far from a simple device. To analyse MOSFET behaviour at HF, VHF and UHF is very difficult, so taking an empirical stance, several features are observed:

As the gate drive rises, the capacitances within the device can (depending on device structure and drain volts applied) shift in a distinctly non-linear manner – it's not a true capacitance, but more charge storage, the energy stored being $\frac{1}{2}CV^2$;

The parasitic NPN transistor will switch if current can get into the "base" – for instance, via capacitances; the transistor can, in some structures, form a part of an NPNP thyristor;

The P-N junctions act as varactors, and combined with the extremely fast nature of MOSFETs, cause some transistors within the device matrix to become UHF oscillators.

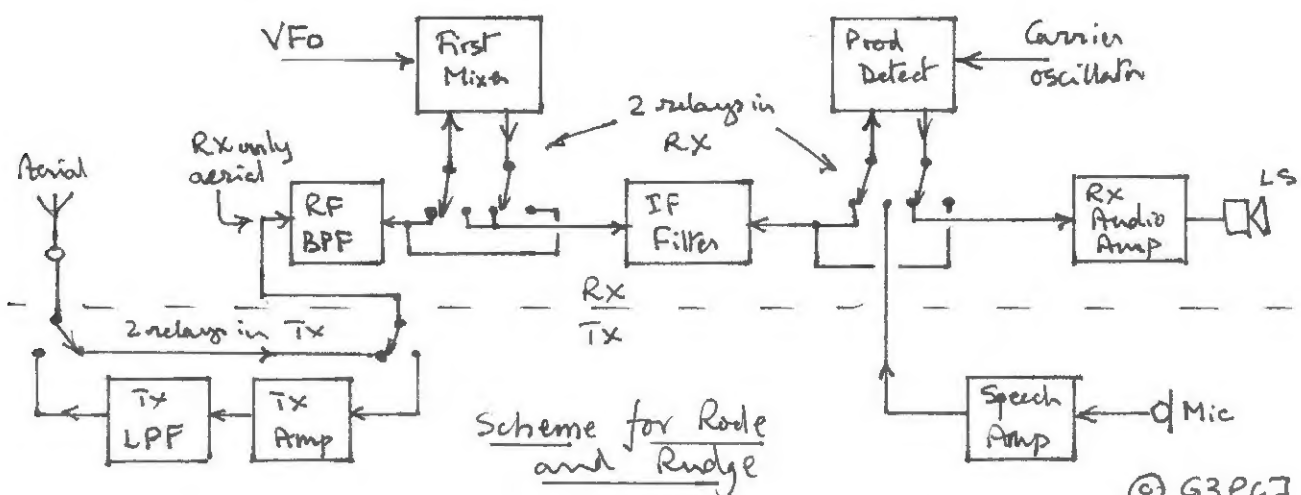
An effect in power MOSFETs designed for switching (IRF510, for instance) used in RF amplifiers, is the higher the drain supply, the more efficiently the device seems to run at high frequencies. This is (probably!) because higher drain voltages widens the inherent diode depletion layers, decreasing stored charge and base current in the parasitic NPN.

Despite their inherent Devils, MOSFETs are useful and cheap devices that can give valiant service in arduous (amateur!) roles. But they are not a universal fix; MOSFETs can cause unexpected parasitic oscillations and non-linearity. A bipolar BD139 has an Ft of >180MHz, 80v V_{ceo} and 1.5 Amp I_c with a V_{ce-sat} of ~ 120mV (corresponding to R_{ds on} of 0.08 ohm), costs £0.20p and won't be unstable if used sensibly. By all means try MOSFETs, but keep in mind bi-polar transistors can also give robust, excellent service at low cost.

Rig Ideas!

Now the Minster is getting near release, it has been timely to review my range of rig offerings because I might have nothing new to think about! At the bottom end, the FiveFET is about the simplest that one can make a usable RX suited to newcomers and electronic construction. This has made the single band version of the Cary redundant and I have now retired it. I had thought of making that into an any HF band regen RX but the options are too great for the probable demand. But it did throw up the fact that a matching simple CW TX would have to be crystal controlled, and hence need a stock of them for 'all' bands! Furthermore, my current simple CW TX (the Kilton) could do with an update to add sidetone etc. Adding these possibilities together, I am now mulling over a new regen RX for 20, 30 and 40m. (The regen approach makes band switching much easier than with a conventional DC RX.) This RX would be aimed at CW primarily and a later variant might do 30, 40 and 80m instead - when 80m becomes more active! The matching CW TX would start as a single band crystal controlled rig with the inevitable few kilohertz of tuning range - but most keen QRP operators don't stray far from the band calling frequencies so that is perhaps not the problem one might expect. The PCB would be drilled for 3 crystals. The output low pass filters need a bit of thought, but luckily an old kit design with twin relay selected low pass filters is just the job to add to the new 1 or 3 band TX! This RX & TX are likely to be called the Mark and Meare. They are a better proposition than the complex four band Cadbury design so I have decided against progressing that project, BUT, I do have four sets of PCBs for the Cadbury Castle and I did do all the writing, so I am happy to turn these into specials - contact me if interested please. (The Castle has a direct conversion CW RX with VFO operation on all bands 20 - 80m; full break in 1.5W TX with sidetone. £80)

Steve Hartley also advises me that often his Buildathon students want to build a superhet RX for 20m, or sometimes 40m. The latter is challenging with an IF of 6 MHz so I am toying with a 10 MHz IF approach that could more easily do 20 and 40, or even 80m without too much trouble. One idea is to layout the PCB for relay switching of the IF strip and RF BPF, so that it could drive a simple SSB transmitter after a few tracks had been cut around the normally absent relays in the plain RX! The RX would then eject low level RF out of its antenna terminal when transmitting which then drives a conventional RF transmit amplifier; for cheapness, this might only be a 1.5W design using three BS170s in parallel like the Fivehead years ago! The only other function required in the transmitter is a speech amplifier so this will easily fit onto a half PCB that can be easily installed behind the RX. As a precaution to prevent pulling, the VFO in the RX ought to be a separate device from the SA602 first mixer, but in other respects it needs nothing else for its transmitter driving role! Partial block diagram below. They have provisionally been given the names of Rode and Rudge for RX and TX. G3PCJ



Valve TX output networks

There are at least two commonly used networks for matching between the output valve load of a few Kohms and the normal 50 Ohm antenna 'load' - see right. Even obtaining as little as 5W with a 2K load implies a 100 v RMS voltage! So apart from any DC voltages also present on the valve anode, there are also quite a lot of RF volts - neither of which are welcome with modern components intended for semi-conductors! There is a particular problem in obtaining variable capacitors that can stand more than a few tens of volts that are possible with PolyVaricons! Sadly, low cost air spaced variables are just not available and the kit designer cannot sensibly use them.

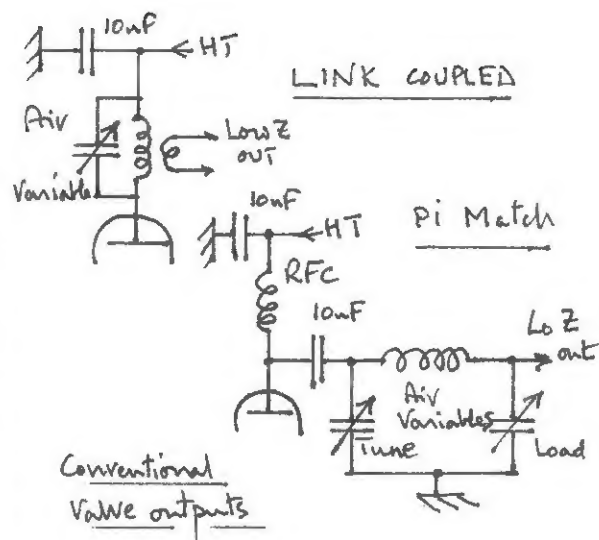
What about using a non resonant RF transformers? Certainly possible and it would make any following matching network use a smaller impedance transformation ratio, which will of course also help reduce the RF voltages at the high impedance end. However, one might argue that if you use any broadband RF transformer to get down from say 2K to 500R, then you might as well go all the way from 2K down to 50R in one go! But beware! Conventionally, the output circuit is resonant at transmit frequency with a Q of about 12 in order to remove unwelcome harmonics, particularly with a Class C output stage. Un-tuned would not do this!

So can we use some other network? Maybe! In receiver tuned circuits, the 50R aerial is often matched by tapping down either the resonating capacitor or inductor. In principle this approach can be used at higher power levels so that a slightly larger ^{resonating} capacitor acts in series with a large one which actually drives the load - this causes the high voltage to be across the smaller one. Small high voltage caps are available but not in adjustable form so maybe you need vary the inductor to tune the network! The obvious alternative is to use a tapped variable inductor with a single resonating low value capacitor.

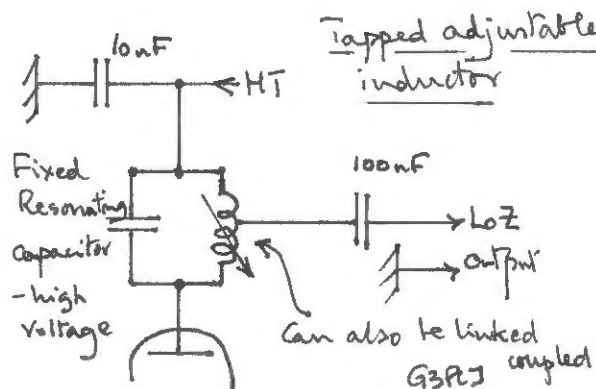
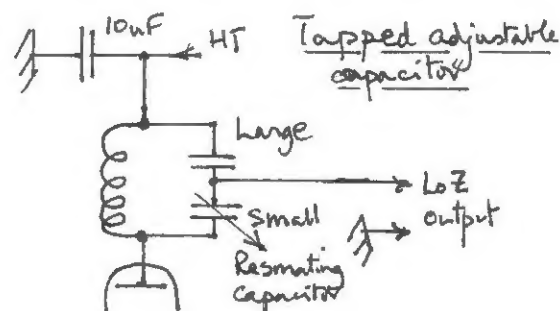
Variable inductors are perfectly feasible - its just a case of how to do it! Years ago one would use a variometer but that is a bit challenging mechanically, an alternative is to move a tuning core in or out of the coil. Ferrite or brass are possible materials and I have seen adjustable lipstick holders pressed into service for an AMU! The hunt is on for cheap coarse threaded mechanisms!

Snippets No 1! You can now use your inkjet printer to directly print a metallic film straight onto an insulating board to make your printed circuits! The cartridge is re-loaded with a suitably conductive ink and away you go! I shall stick with copper clad fibre-glass for while yet!

No 2! One home constructor (un-identified!) wished to use a small simple medium wave RX (with a ferrite rod antenna using AM) around his house while listening to his favourite audio tracks! He cobbled together a series emitter follower audio modulator stage (driven by the audio source), with the RF output derived from a 1 MHz clock oscillator plus MOSFET driving a wave-wound large coil resonated to 1 MHz! Legal?? I think not. Tim



Conventional
Valve outputs



QRP vs. serious QRO in Riyadh by Andrew ZL2PD

I'm in the final stages of finishing off one of Tim's Lydford transceivers. I'm building it for use on 40m. One of the main reasons for selecting that band is interference – I expect it to be less of a problem listening to signals on that band here than if I built the kit for, say, 20m. The main source of interference also is a bit closer for me than most. It is located a little way up the road from where I presently live, in Riyadh, Saudi Arabia.

Just a few kilometers away, there's a Medium Wave and Shortwave transmitting station where a large number of 250kW, 500kW, 1MW and 2MW broadcast transmitters are located. These feed a dedicated array of high gain curtain array antennas on shortwave, some AM verticals, and at least one large log periodic antenna. The curtain array's 49 towers (by my count) are arranged in three radial arms, the transmitting station at the centre. The antenna farm is clearly visible when driving east out of the city.

The truly vast area of land set aside for these transmitters and arrays is completely surrounded by literally miles and miles of high sandstone walls topped with barbed wire. Unless you are some distance away and slightly elevated, there is little to see. And, frankly, it's unhealthy for a number of reasons to attempt to look at (or still worse, photograph) the site close-up.

The towers hold up the somewhat outdated HF curtain arrays on each of the three radial arms of the main HF array. These curtain arrays can easily add another 10 or 20 dB to the signal level in the target receiving region. I was also told that when the nearby National Stadium steelwork was being erected a few kilometers away, the induced voltages from the high RF levels were high enough to generate severe arcing across the gaps as the large steel trusses were being moved into position for final bolting. You might also notice a log-periodic antenna, although it's not clear if it is still in use.

Naturally, a power supply is needed for all these transmitters. My Lydford is powered by a small recycled 12VDC 4A DSL router power supply which weighs about 500 grams. In this case, there is a very large power station with multiple generators a little further up the highway supplying power to these transmitters, along with a vast collection of oil tanks to fuel the generators. Don't the problems just grow when you're not running QRP?

Depending on the time of day, these transmitters operate on 9, 11, 15, 17 and 21 MHz. The schedule suggests there's also a brief mid-afternoon burst on 7MHz but I've not heard that one. Probably while I'm at work.

As expected, the double-tuned front-end on the 40m Lydford receiver has adequate selectivity to deal with these 9 – 21 MHz signals, especially given my modest receive antenna. I can hear a little interference as a varying mushy low level background noise when the 9MHz transmitters kick off. That's hardly any surprise given their power and proximity, and it presents little bother to me. On 20m, however, things can be distinctly more difficult for receivers as a result of the numerous nearby high power carriers. I have to use a receiver with a seriously high performance front end to survive in that RF environment.

I used a full size Rhombic some years ago on a remote island in the middle of the Pacific. That was a real treat to use with my Icom HF transceiver. I enjoyed my S9++ reports from placed many thousands of kilometers away.

It's a wonderful dream, but sadly completely out of the question, to try one of those curtain array or that log periodic antenna. Still, for the sake of argument, could I still call it QRP if I used a 16dBi gain curtain array with my Lydford?

Note by Tim - I did have some photos of similar towers and aerial arrays etc to give you an idea of what this lot must look like, but I know they will not photocopy well, so I am afraid that I decided against including them.

I also know that Andrew has been experimenting with an alternative DDS VFO to drive his Lydford. I hope he will be writing that up for us next time! As ever, I suspect we will hear that it is all about compromises!

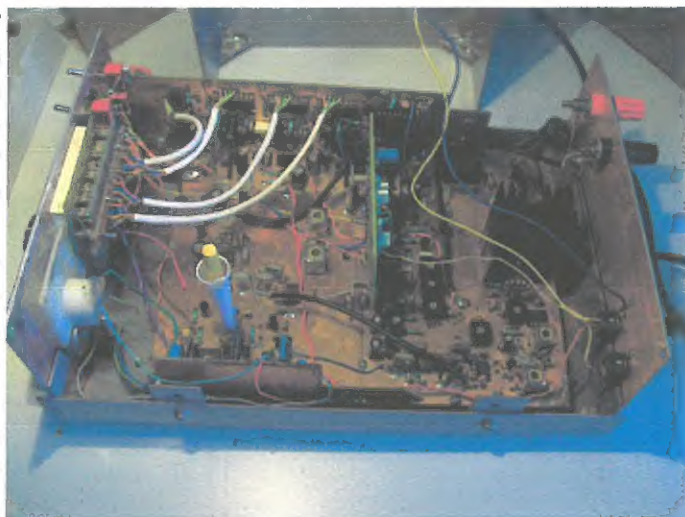
Encasing Rigs by David Seabrook G4LJG

David has sent along some excellent photos of his two Midneys and Kingsdons, complete with counters and other add-ons! He says:-

"My method of making cases uses double sided PCB material cut to size using an electric diamond wheel tile cutter, which cuts them (either fibre glass or paxolin) much more cleanly than a saw or Stanley knife. You must use water because the dust of both is dangerous! First I tape the top and bottom boards together so they cannot move, set the saw to the measurements needed and cut both boards together, using the same method for front and sides.

I then spray-paint them usually with Hammerite as it is very hardwearing. For the front and back I usually use a matt colour (often cream) and then apply Lettraset transfers when it is dry. This is then covered with clear film that is used for covering car number plates or plastic signs as that is also very hard wearing! It is very sticky and once it touches any surface, it cannot be moved!

My method with the film is to cut it about 3/4 inch oversize, and then peel back about 1 inch starting at one end, applying it from one end while rubbing the film onto the panel with a side to side action thus making sure no air bubbles are trapped and only exposing the film as I go, otherwise it is likely to touch the surface before I want it to, or to fold onto itself and hence become impossible to correct! I then cut the corner across and fold the film over the edge, then cut the holes for controls.



David also comments on his special tuning control as seen left! He got fed up having to remove the cover to adjust between band sections for CW and SSB! All he did was to cut a silicon tube nozzle to fit the top of the TOKO coil can, then used an epoxy glue to attach an old tuning tool filed to suit the core. "I was doubtful at first whether it would work all right" but since he has had it working he has logged up VE, CU, SP, UA, DK/J, IK on both phone and CW! The counter makes adjustment so much easier! He gets good reports especially on the audio so feels there cannot be much wrong! I should explain that David also makes proper sized fishing rods so knows what he is up to in mechanical matters! Tim



Happy Christmas to you all!